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NASA

Nuclear Thermal Propulsion

Space Transportation Propulsion Technology Symposium

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DIRECT FISSION-THERMAL PROPULSION PROCESS

NUCLEAR ENERGY

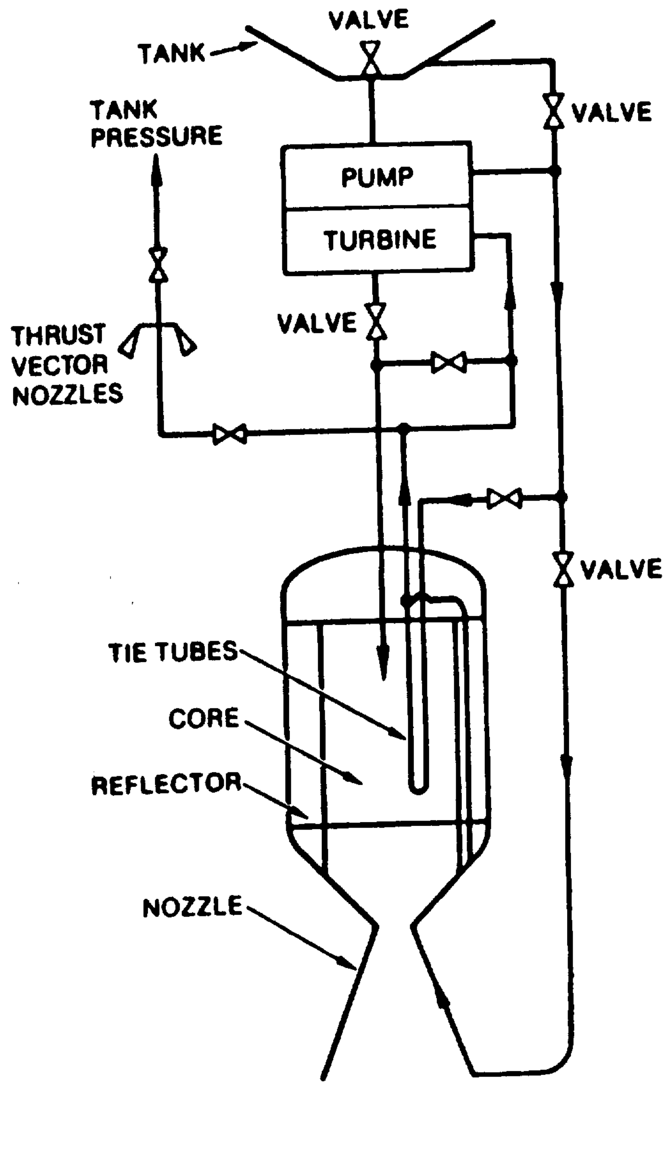
FRAGMENT KINETIC ENERGY

THERMAL ENERGY

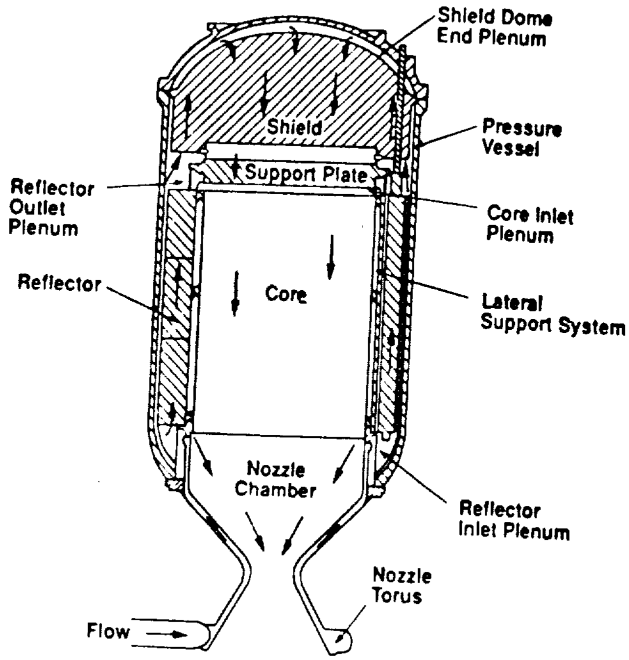
THERMODYNAMIC EXPANSION

DIRECTED THRUST

NUCLEAR ENGINE SCHEMATIC



Typical Rocket Propulsion Reactor

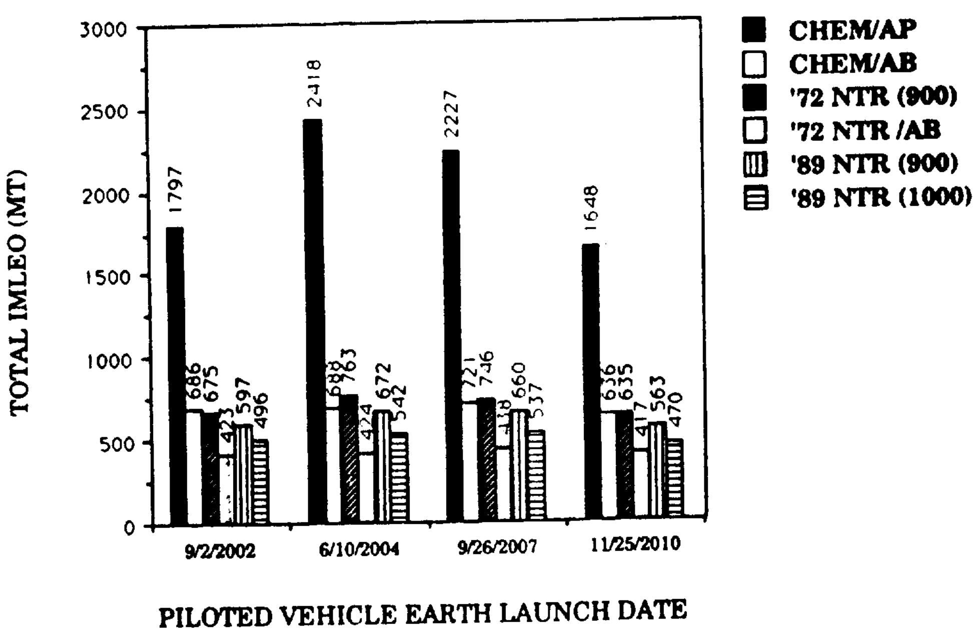


DIRECT FISSION-THERMAL PROPULSION -- ADVANTAGES

- HIGH SPECIFIC IMPULSE (860s - 1000s)
- HIGH THRUST-TO-WEIGHT
- NOT ENERGY LIMITED (AUX. POWER OPTIONS)
- REUSABLE
- THROTTLEABLE (25% - 100%)
- MONO-PROPELLANT
- MULTIPLE PROPELLANT CHOICES (H_2, NH_3, . . .)
- NEAR-TERM TECHNOLOGY (IT WORKS!)

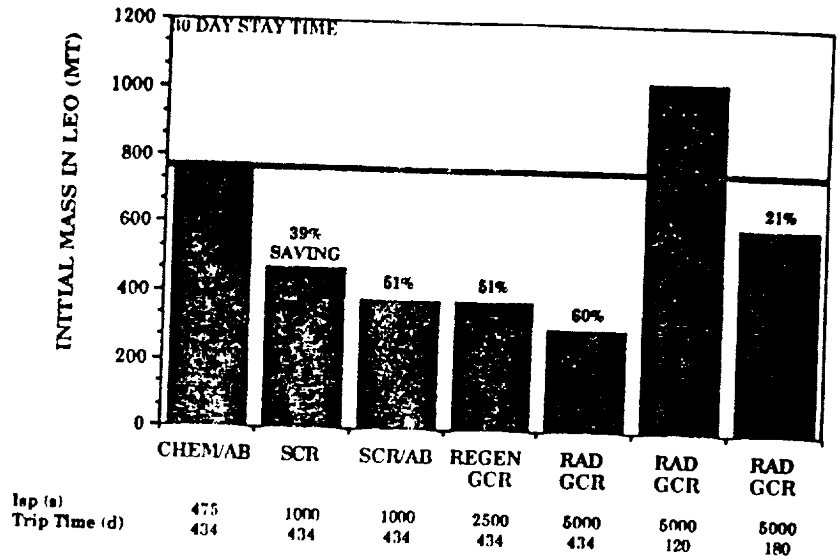
MISSION APPLICATIONS OF DIRECT FISSION-THERMAL PROPULSION

- ORBIT TRANSFER VEHICLE
- LUNAR TUG
- PILOTED MARS MISSION
- EXTRA-TERRESTRIAL RESOURCE UTILIZATION

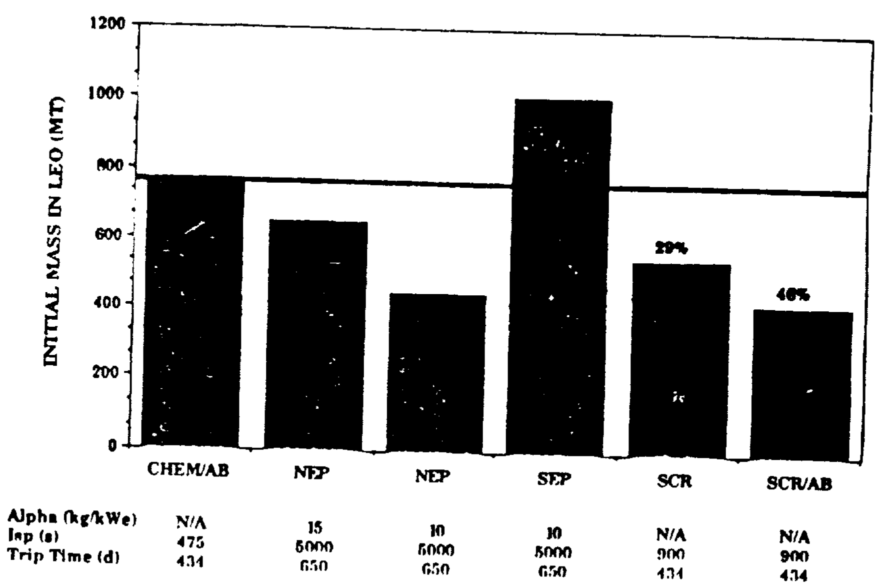


MARS EXPEDITION CASE - IMLEO SENSITIVITY TO LAUNCH OPPORTUNITY

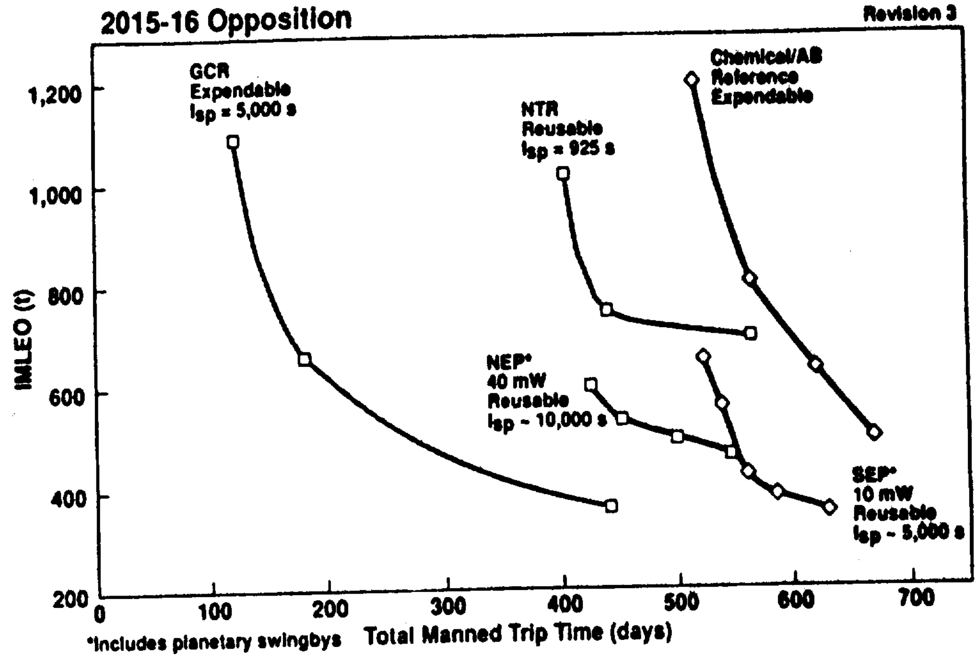
PROPULSION PERFORMANCE COMPARISON
SCR AND GCR PILOTED MARS MISSIONS, QUICK TRIPS



PROPULSION PERFORMANCE COMPARISON
NEP, SEP, AND SCR PILOTED MARS MISSION



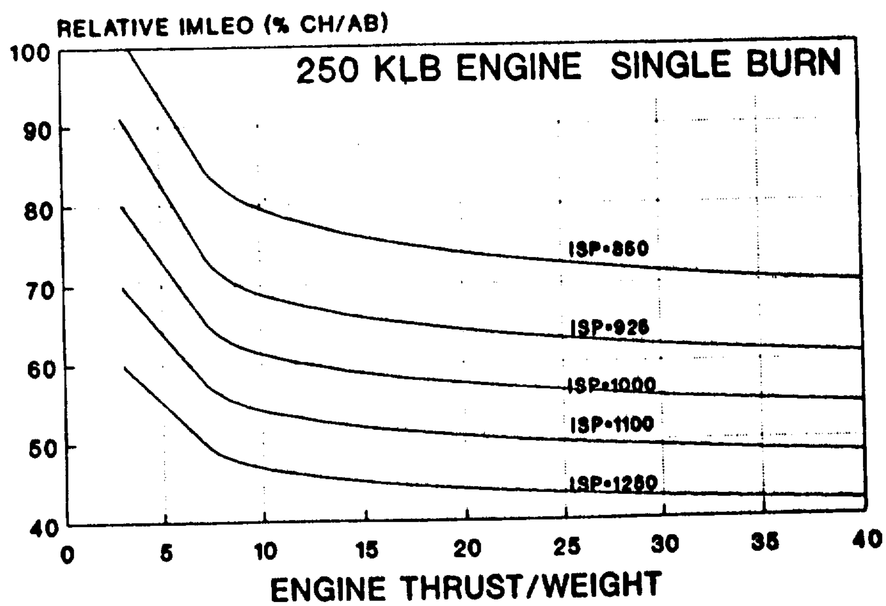
Various Opportunities For Given MTV Propulsion Options



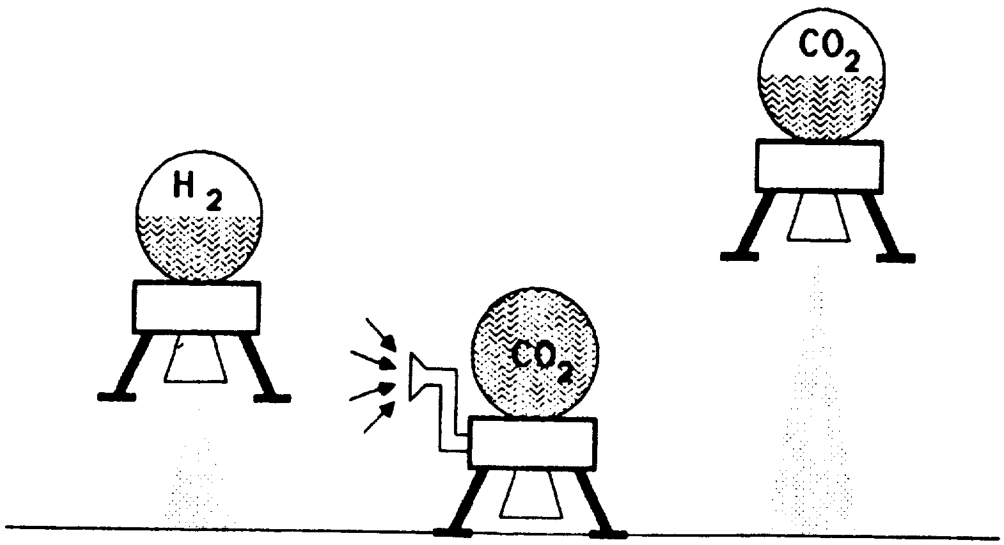
*Includes planetary swingbys

Ref: Boeing - Advanced Civil Space Systems

NTR MARS PERFORMANCE THRUST/WEIGHT AND ISP VARIATIONS



EXTRA-TERRESTRIAL PROPELLANT LANDER/HOPPER/ASCENT VEHICLE (DIRECT FISSION-THERMAL PROPULSION)



Land on Mars with Hydrogen

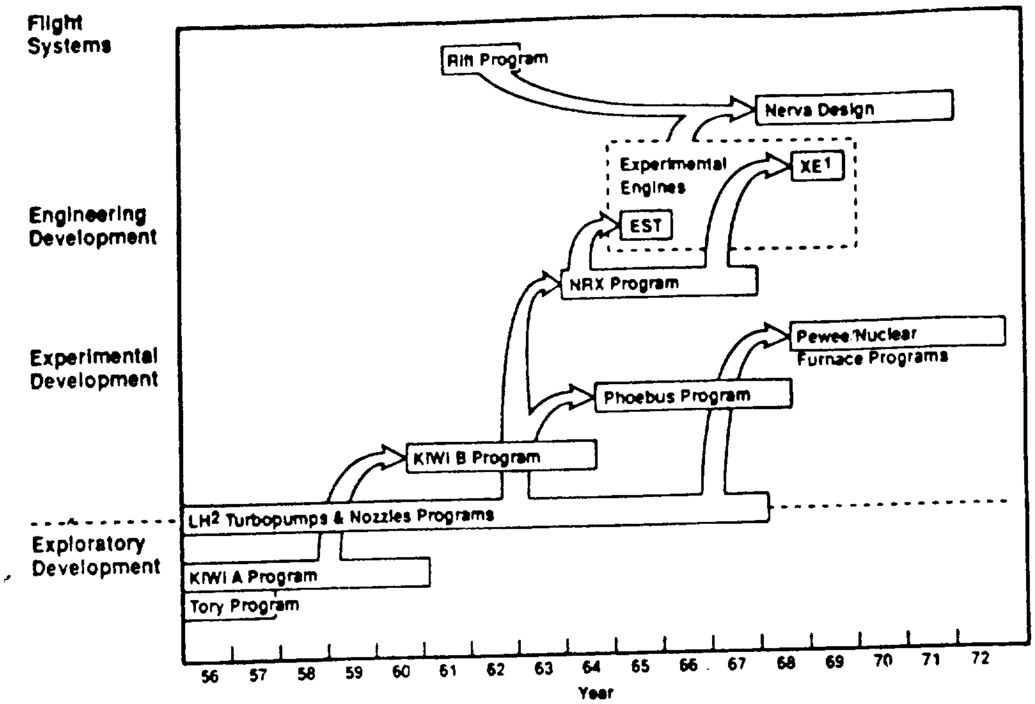
Refuel with CO_2

Launch with CO_2

DIRECT FISSION-THERMAL PROPULSION SYSTEMS

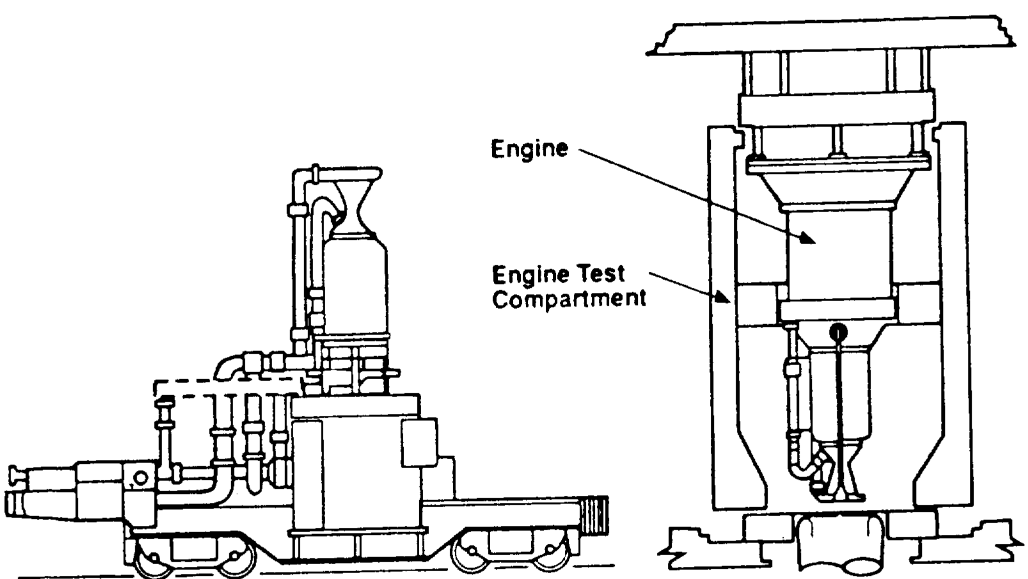
	NERVA	ANRE (INEL)	PBR (BNL)
THRUST [kN]	333	65	44
I_{sp}[s]	825	900	900-1000
MASS FLOW [Kg/s]	41.2	7.4	4.5
POWER [MW_T]	1500	370	200
WEIGHT [10^3Kg]	10.4	2.1	0.6
THRUST/WEIGHT	32	31	73
FUEL	UC	UC·ZrC-C	UC·ZrC
MODERATOR	C	ZrH	LiH, Be, ZrH

Nuclear Rocket Program



NERVA Engine Technology Testing

Test Stand Superstructure



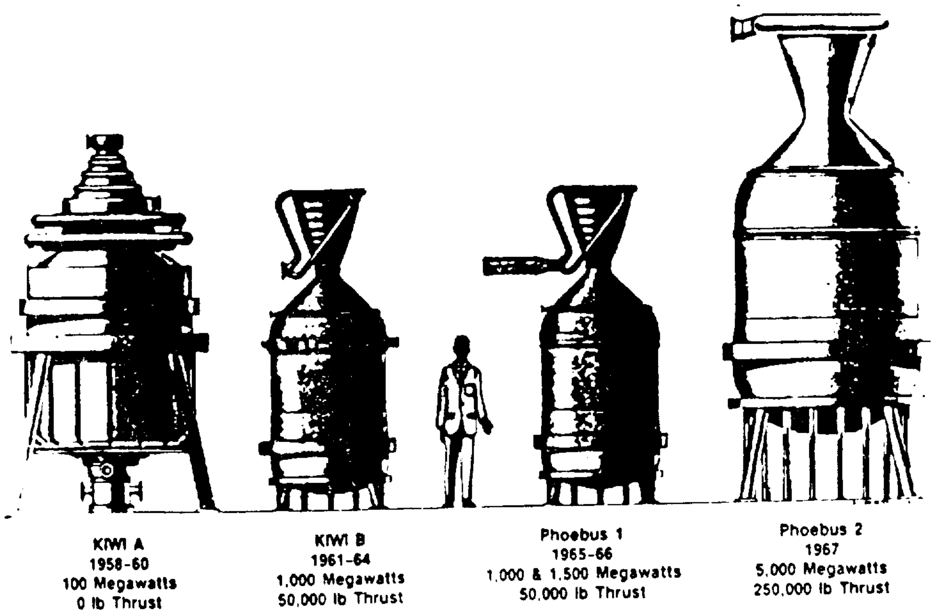
Breadboard Engine System Test (NRX/EST)

Ground Experimental Engine (XE)

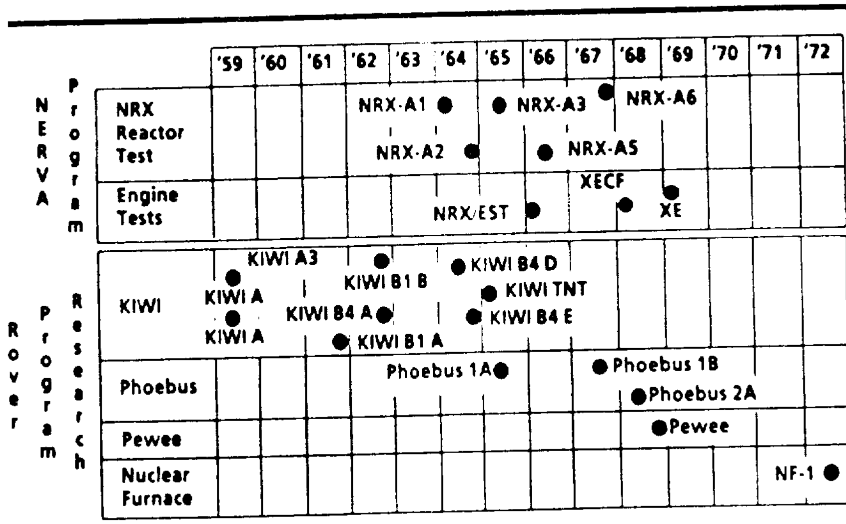
What we are attempting to make
is a flyable compact reactor,
not much bigger than an office
desk, that will produce the
power of Hoover Dam from a
cold start in a matter of minutes

-- Dr. Glenn T. Seaborg
Chairman
Atomic Energy Commission

Evolution of Rover Reactors



NERVA/Rover Reactor System Test Sequence



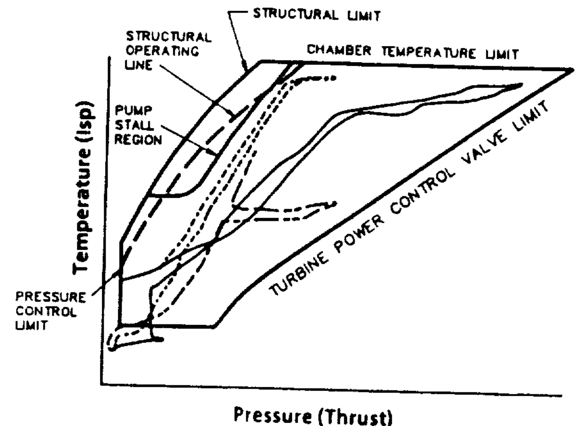
Flexibility Demonstrated in Ground Experimental Engine (XE) Test

TEST PERIOD, 3/20/69–8/28/69

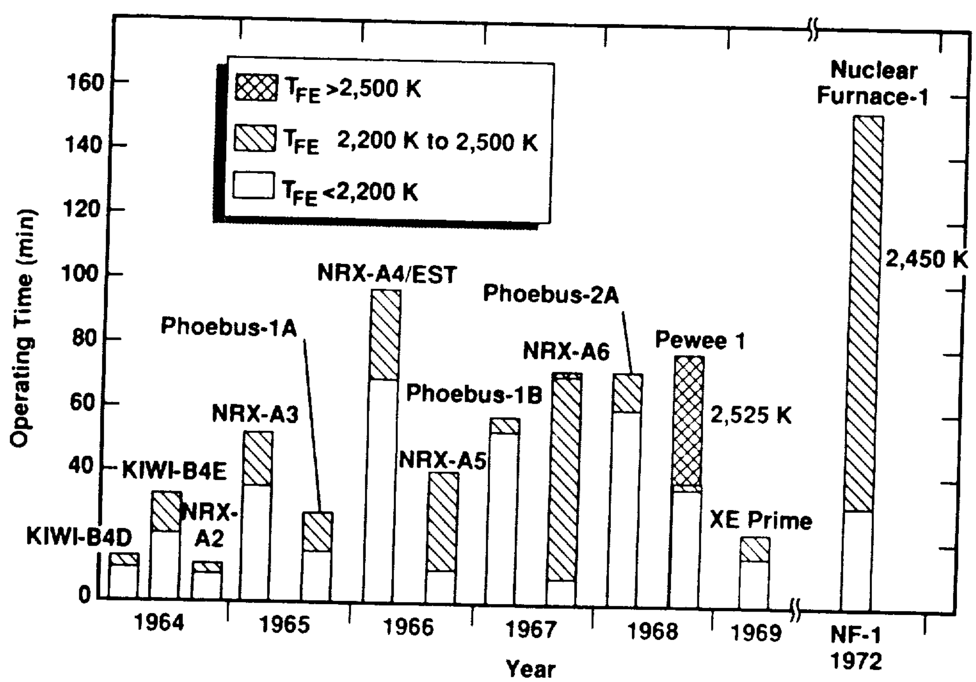
EXPERIMENTS CONDUCTED

STARTUP INVESTIGATIONS	15
PERFORMANCE CHARACTERISTICS AT HIGH POWER	6
ENGINE DYNAMIC PERFORMANCE	10
FACILITY EVALUATION	4

SUMMARY – 28 STARTUPS
3 HOURS 48 MINUTES OF OPERATION



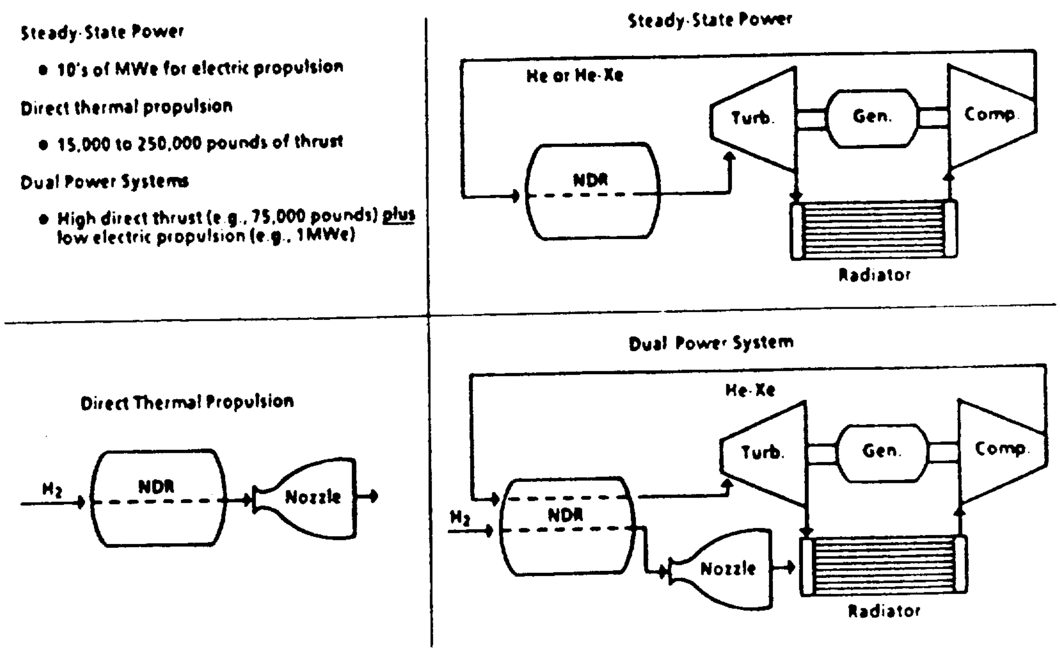
Operating Time vs Temperature for Nuclear Rocket Program



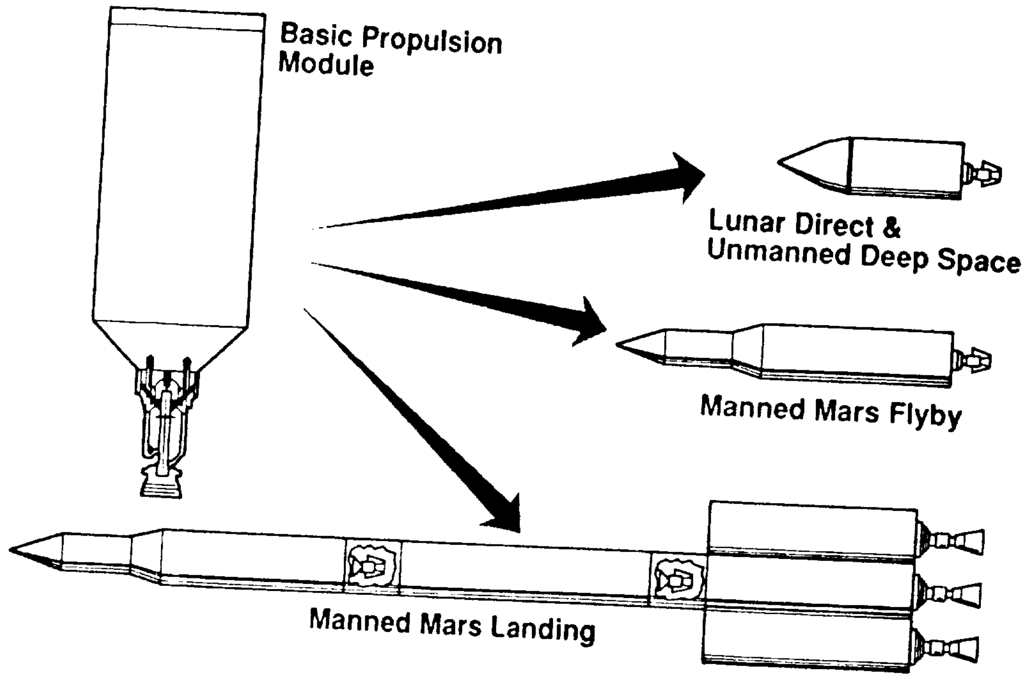
Major System Test Results

- Demonstrated power capability
  - 1100 MWt in NRX (55,000 lbs thrust)
  - 4400 MWt in Phoebus (220,000 lbs thrust)
- Demonstrated power, temperature and flow stability
  - High specific impulse (800-900 seconds)
  - High thrust startup
- Demonstrated reactor/engine endurance – 60 minutes in NRX-A6
- Demonstrated reactor/engine maneuverability - 28 startup cycles in NRX-XE
- Demonstrated reactor fuel – 10 hours 40 minutes and 64 cycles

NERVA TECHNOLOGY HAS SYNERGISTIC APPLICATIONS



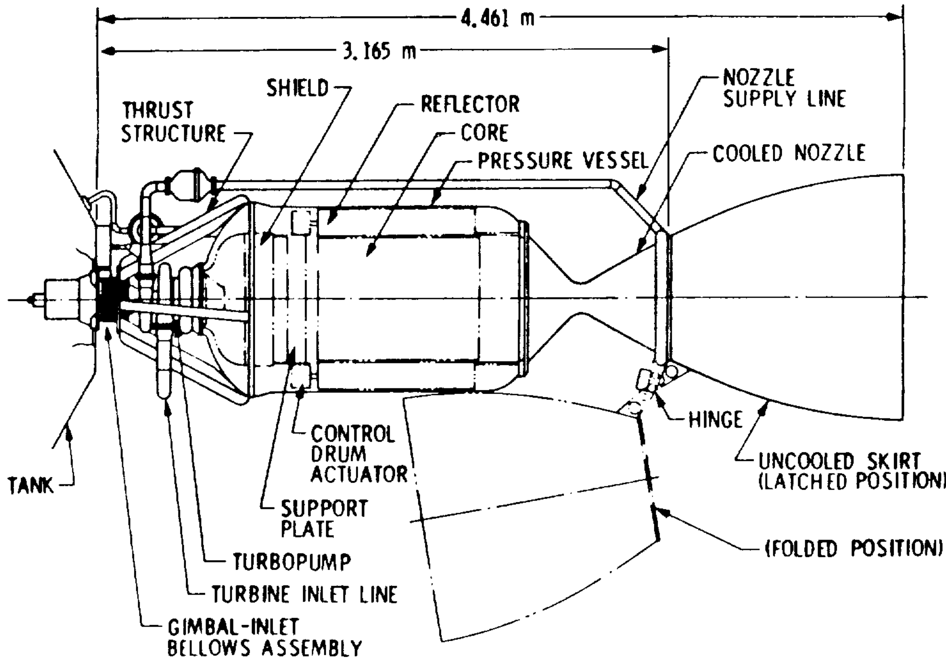
Versatility



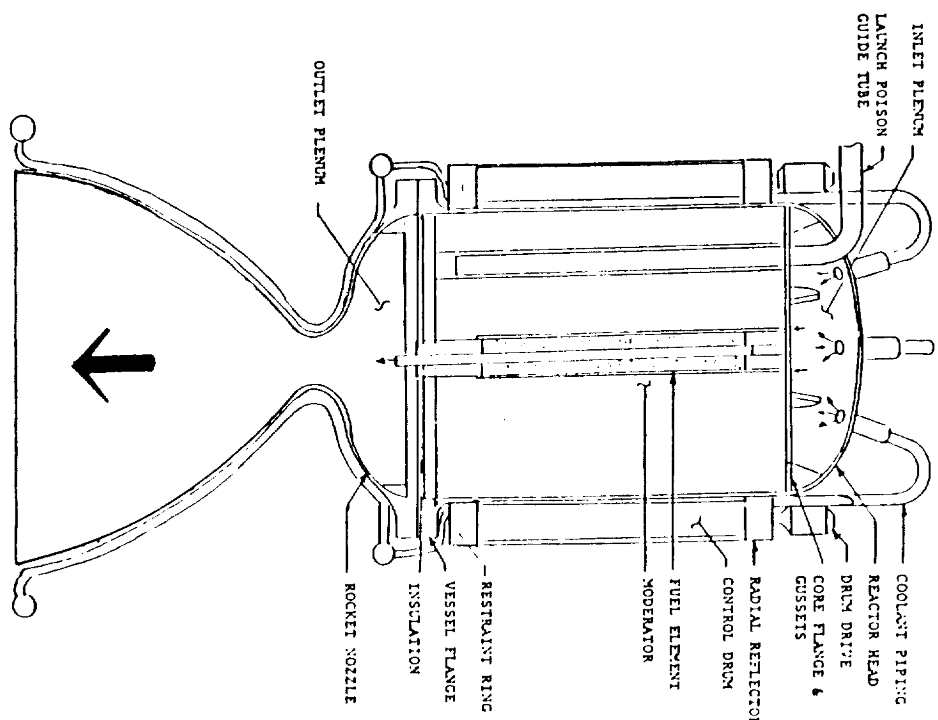
NERVA DESIGN - STATUS

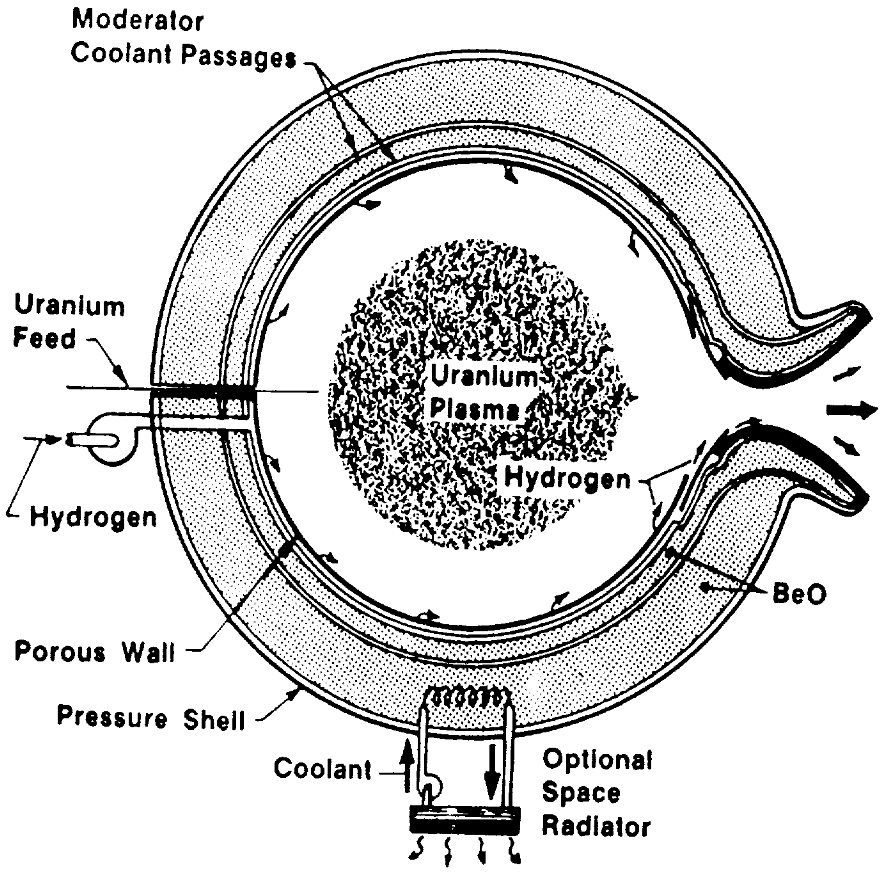
- DEVELOPED DURING PROJECT ROVER
- FULL POWER, FULL DURATION TESTED
- FLIGHT QUALIFIABLE DESIGN UNDER WAY AT CONCLUSION OF PROJECT ROVER
- EXPERTISE STILL AROUND (JUST BARELY)
- WESTINGHOUSE FULL-DESIGN BLUEPRINTS INTACT
- LANL CAN STILL EXTRUDE FUEL SEGMENTS
- FUEL SEGMENT TEST FACILITIES AVAILABLE
- FULL SCALE TEST FACILITIES UNAVAILABLE

SMALL/ADVANCED NUCLEAR ROCKET ENGINE
(SNRE/ANRE - LANL/INEL)

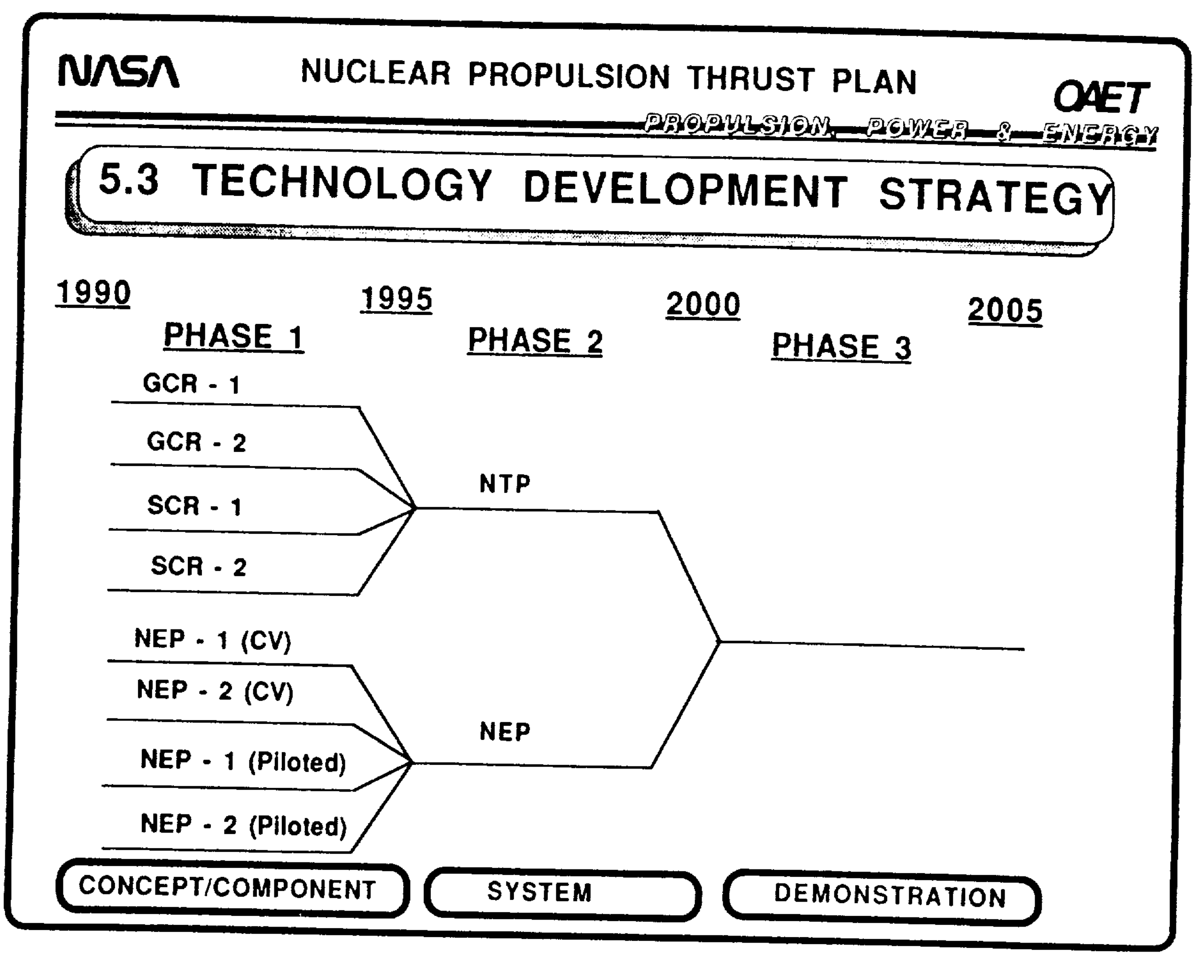


PARTICLE BED REACTOR DESIGN





Moderator
Coolant Passages
Uranium
Feed
Uranium
Plasma
Hydrogen
Hydrogen
BeO
Porous Wall
Pressure Shell
Coolant
Optional
Space
Radiator



NASA
NUCLEAR PROPULSION THRUST PLAN
OAET
PROPULSION, POWER & ENERGY
5.3 TECHNOLOGY DEVELOPMENT STRATEGY
1990
1995
2000
2005
PHASE 1
PHASE 2
PHASE 3
GCR - 1
GCR - 2
SCR - 1
SCR - 2
NTP
NEP - 1 (CV)
NEP - 2 (CV)
NEP - 1 (Piloted)
NEP - 2 (Piloted)
NEP
CONCEPT/COMPONENT
SYSTEM
DEMONSTRATION

NASA NUCLEAR PROPULSION THRUST PLAN OAET

PROPULSION, POWER & ENERGY

EXECUTIVE SUMMARY

KEY TECHNICAL ISSUES

Safety/safeguards/QA
(during all program phases)
Qualification/acceptance test strat.
Reliability and fault tolerance
High Performance engines
(including reactors)
Reusability/restart capability
Reactor Fuel
Structural Aspects
Turbomachinery
Vessels/Nozzles
Pumps/Valves
Diagnostic Capability
Control Systems (neutronics/
I&C)

Power Processing Units
(NEP)
Thrusters (NEP)
Space operations
- radiation shielding
- design criteria for in-space
operation and
maintenance
Propellants/Prop. handling
Thermal hydraulics
Thermal Management
Materials
Lifetime
Mass/Volume Limitations
In-situ Prop. Utilization

LET'S GO TO MARS!

FUSION PROPULSION